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Authors: Kock, Michael D., and Berger, Joel

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CHEMICAL IMMOBILIZATION OF FREE-RANGING NORTH AMERICAN BISON (*BISON BISON*) IN BADLANDS NATIONAL PARK, SOUTH DAKOTA

Michael D. Kock[1] **and Joel Berger**[2]

[1] International Wildlife Veterinary Services, Inc., P.O. Box 1413, Orangevale, California 95662, USA
[2] Department of Range, Wildlife and Forestry, University of Nevada, Reno, Nevada 89512, USA

ABSTRACT: Twenty-six free-ranging North American bison (*Bison bison*) (22 adult bulls, one yearling male and three adult females) were immobilized using a combination of carfentanil and xylazine. For carfentanil the dose range (mean ± SD) was 1.8–5.0 μg/kg (2.4 ± 0.7 μg/kg) and for xylazine 0.004–0.125 mg/kg (0.07 ± 0.03 mg/kg). Induction time (mean ± SE) was 14.2 ± 2.9 min (median 8 min), while the total mean reversal time after administration of a narcotic antagonist was 9.0 ± 1.4 min (median 8 min). Only one animal that received the highest initial dose of carfentanil (2.5 mg) showed evidence of becoming "re-narcotized." Five animals required two or more doses of carfentanil before becoming immobilized. Overall, small volumes of drug used (mean = 0.62 ml for carfentanil, 0.53 ml for xylazine) enabled the use of 1 to 2 ml darts, increasing both accuracy and impact safety. Darting success approached 100%.

Key words: *Bison bison*, free-ranging bison, immobilization, carfentanil, xylazine, naloxone, yohimbine.

INTRODUCTION

Many species of large mammals exist in remnant or "island-like" populations in which there is little or no gene flow. Concern has been amplified regarding the potential deleterious consequences of inbreeding (Ralls et al., 1979), but important genetic data are lacking for many of these populations since individuals cannot be handled. North American bison (*Bison bison*), the largest native land mammal in the New World (Reynolds et al., 1982), is a good example of such a genetically isolated species occurring in several national parks and numerous refuges in North America. Although chemical immobilization of free-ranging and captive wildlife is well documented (Harthoorn, 1975; Fowler, 1978, 1986; Nielsen et al., 1982; Wallach and Boever, 1983) there are few reports on the use of potent narcotics on either free-ranging or captive bison, and these are limited to etorphine (M99) (Haugen et al., 1976; Boever, 1986).

The development of more potent narcotic derivatives, such as carfentanil, has made it possible to utilize small drug volumes and concomitantly smaller projectile syringes to increase darting efficiency and safety. The use of carfentanil is reported in captive (Jessup et al., 1984; Stanely et al., 1984; Wiesner et al., 1984; Karesh et al., 1986) and free-ranging wildlife (De Vos, 1978; Haigh et al., 1983; Franzmann et al., 1984; Meuleman et al., 1984; Jessup et al., 1985; Seal et al., 1985), but not in bison. As part of a continuing study on the genetics and behavioral ecology of bison it was necessary to immobilize individual animals. This paper reports on the use of carfentanil and xylazine to immobilize free-ranging North American bison in Badlands National Park, South Dakota, USA.

MATERIALS AND METHODS

In Badlands National Park about 400 bison roam freely over the 250-km² Sage Creek Wilderness Area (SCWA). Unlike many other areas with free-ranging bison (Wind Cave National Park, Fort Niobrara Wildlife Refuge, National Bison Range, etc.), access to the SCWA is restricted to foot or horseback because of the federal designation of "wilderness area." Although many bison in the Badlands are captured with the aid of vehicles when they wander outside

the wilderness area (where they may be restrained in corrals), after 2 yr of study many of the bulls and some recognizable cows had not been restrained. Immobilization was the only feasible way to gather data on these important, but elusive, animals. Twenty-six free-ranging bison (22 adult bulls, one yearling male and three adult females) were immobilized from 17 to 27 September 1986.

Bison were located visually, identified, weights estimated and, when suitable animals were found, a dart was loaded just prior to stalking or approaching the bison. Most of the bulls were solitary or in small groups and were sighted from the north rim of the SCWA. Animals targeted for immobilization usually were unaware of our presence or appeared unconcerned. Considerable effort was expended to minimize excitement and disturbance of these animals. The majority of animals remained in the area following darting, but occasionally individuals or groups stampeded for 0.5 to >1.6 km.

The drugs used for immobilization were stored in a refrigerator when not in use, or carried in a cold pack in the field. Carfentanil (Wildnil, Wildlife Laboratories, Inc., Fort Collins, Colorado 80525, USA) was used at a concentration of 3 mg/ml and xylazine (Rompun, Bayvet Division, Miles Laboratories, Inc., Shawnee, Kansas 66201, USA) at 100 mg/ml. Naloxone (Sigma Chemical Co., St. Louis, Missouri 63178, USA) at 50 mg/ml, was used as a reversal for the carfentanil. Yohimbine at a concentration of 5 mg/ml (Antagonil, Wildlife Laboratories, Inc., Fort Collins, Colorado 80525, USA) was used to reverse the effects of xylazine. A separate syringe loaded with naloxone was carried for human emergencies.

The immobilizing drugs were loaded into either 1-, 2- or 3-ml Pneu-Darts with 2.5–3.0-cm gelatin-collared needles (Pneu-Dart, Inc., P.O. Box 1415, Williamsport, Pennsylvania 17703, USA). Following drug loading the ends of the projectile syringe needles were sealed with Vaseline to prevent spillage and for safety. Darts were delivered by a model 171 Pneu-dart cartridge fired rifle with a four powered scope (Pneu-Dart, Inc.). The majority of the darts were 2-ml capacity; 1-ml darts were used to provide additional drug doses.

Bison were approached usually to within 40 to 50 m and darted in the lateral or caudal thigh. The neck and shoulder were avoided because of the thick mane-like hair. Occasionally, partially sedated animals were further injected by a hand-held syringe.

Following recumbency, bison were approached from behind to ensure that individuals

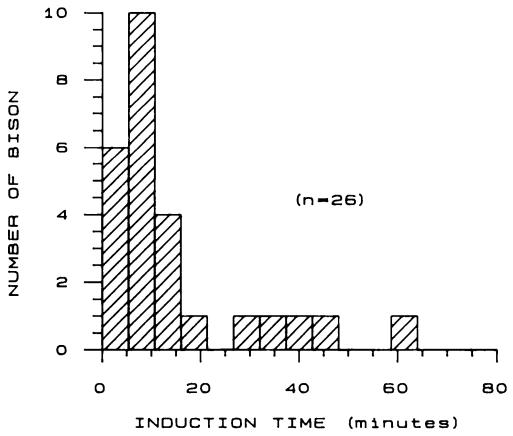

FIGURE 1. Distribution of induction times for North American bison immobilized with carfentanil and xylazine.

were safely sedated. Their eyes were then covered and, if in lateral recumbency, efforts were made to bring the animal into a sternal position. In most cases this was impossible due to the terrain and size of the animal. Ropes were carried to assist in processing animals. Body measurements were taken, blood collected for genetic and other studies, and ages estimated by standard tooth-wear procedures (Fuller, 1959). Blood was collected, optimally from the tail vein, utilizing a venipuncture set. When this was not possible, the tarsal or femoral vein and occasionally jugular vein were used. Basic physiological parameters were taken including temperature, pulse and respiration. When practical, two respiration measurements were taken also at induction and following yohimbine reversal. It was not uncommon to experience difficulty in locating a suitable pulse measuring point due to the large size of the animals. Eventually, the tail artery was utilized successfully.

The collected data were put onto a spreadsheet (SuperCalc 4, Computer Associates International, San Jose, California 95131, USA), and analyzed using a statistical graphics program (StatGraphics, Statistical Graphics Corporation, Rockville, Maryland 20850, USA). Initially exploratory data analysis was performed to evaluate the distribution pattern and then specific statistical tests were used (Daniel, 1983), including one-way analysis of variance (ANOVA) (carfentanil dosage and induction times, naloxone dosage and reversal times) and two-sample analysis using the Student's t-test (comparison of temperature, pulse and respiration between animals receiving multiple or single doses of carfentanil; comparison of respiratory rate prior

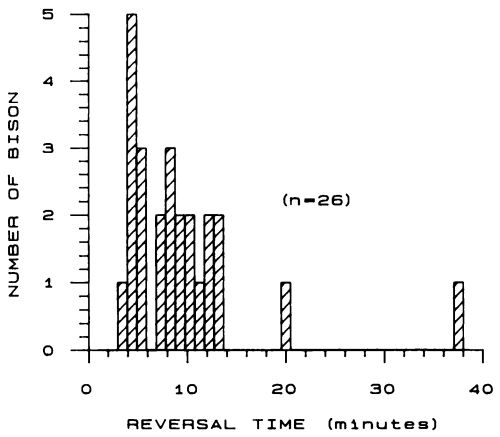

FIGURE 2. Distribution of reversal times for North American bison using naloxone to reverse carfentanil.

to and after yohimbine reversal). The "raw data" for induction (Fig. 1) and reversal (Fig. 2) times were distributed log-normally. With logarithmic transformation, the transformed data more nearly approximated a gaussian distribution for ANOVA. Means are reported with standard deviations (SD) for inferences to individual bison, and with standard errors (SE) for inferences to groups or populations of bison.

Time to first signs of induction refers to the time from dart impact to stumbling, vocalization, lowering of the head or sagging of the hindquarters, and total induction time to sternal or lateral recumbency. Time to first signs of reversal refers to the time from administration of naloxone to movement of the ears, lifting of the head and/or struggling, and total time of reversal to the animal standing and/or walking.

RESULTS

Our results are based on 26 immobilizations and reversals on 25 animals. One of the bulls immobilized was inadvertently re-immobilized 2 to 3 hr later, 5 to 6.5 km from the initial immobilization site. This animal recovered well from both immobilization episodes and was observed in good condition 7 wk after being darted. One indirect mortality occurred, the first bull that was immobilized with 2.5 mg carfentanil and 30 mg xylazine. This bull showed evidence of becoming "re-narcotized" 6–8 hr postimmobilization; there was an increased gait but he appeared to remain alert. When we attempted to find the bull a dense fog intervened; we were unsuccessful. He was relocated later about 11 km outside the park. Because of heavy rainfall, poor visibility and the location of a nearby town he was shot for safety reasons.

The mean estimated weight of the 25 bison that were immobilized was 735 kg (range 193–967 kg). The mean doses of carfentanil and xylazine (mean ± SD) were 2.4 ± 0.7 μg/kg (range 1.8–5.0 μg/kg) and 0.07 ± 0.03 mg/kg (range 0.004–0.125 mg/kg), respectively. The lowest effective dose of carfentanil was 1.5 mg for a bull with an estimated weight of 800 kg. Mean time to sternal recumbency for the 26 immobilizations (mean ± SE) was 14.2 ± 2.9 min. However, the median time to sternal recumbency (8 min) probably reflects more realistically the true induction time since some animals required additional doses of carfentanil and therefore had extended induction times. On average, bison were recumbent for 28 min. The xylazine was reversed soon after induction with yohimbine (mean dose 35.0 ± 1.4 mg, approximately 0.625 mg yohimbine/1 mg xylazine). The narcotic was reversed with naloxone. Nineteen animals received naloxone intravenously (i.v.) (100.0 ± 3.4 mg), intramuscularly (i.m.) (41.0 ± 4.2 mg) and subcutaneously (s.c.) (41.3 ± 4.4 mg); six bison received naloxone (all bulls) i.m. (112.5 ± 8.6 mg) and s.c. (66.6 ± 8.3 mg) only. One animal received an i.v. and s.c. injection. For the 19 animals receiving naloxone by the three injection routes the mean total dose of naloxone was 179.4 ± 8.0 mg, approximately 100 mg naloxone/1 mg carfentanil. The time to first signs of reversal for the 26 immobilizations was 4.1 ± 0.6 min, and total time to standing and ambulatory was 9.0 ± 1.4 min.

Of the 26 bison immobilizations, 20 required a single dose of carfentanil and xylazine to achieve adequate sedation (Table 1), five required two or more doses of carfentanil (Table 2), and one animal that was

TABLE 1. Immobilization data on male and female bison using a single dose of carfentanil and xylazine.

	n	Mean	Median	SE[a]	Range
Carfentanil (μg/kg)	20	2.2	2.1	0.4[b]	1.9–4.0
Induction time (min)	20	9.3	7.0	1.3	4.0–28.0
Arousal time after naloxone (min)	20	10.4	8.5	1.7	4.0–38.0
Total dose naloxone (mg)	20	174.0	175.0	4.9	110.0–225.0
Temperature (C)	18	38.6	38.6	0.1	37.7–39.8
Pulse (bpm)	16	74.8	73.0	6.5	42.0–120.0
Respiration (bpm)	17	22.4	7.9	4.4	12.0–42.0

[a] Standard error.
[b] Standard deviation for carfentanil dosage, SE for all other values.

initially sedated with xylazine required a dose of carfentanil.

Induction times for those bison requiring multiple doses of carfentanil were significantly different from bison requiring single doses ($P < 0.002$) (Fig. 3). However, significant differences between these groups were not found in the time to first signs of induction. Induction in bison was characterized by lowering of the head, chewing, deep vocalizations and a slow sagging of the hindquarters. Most bulls remained near the darting area and went quietly into either sternal or lateral recumbency. Lateral recumbency was initially characterized by wallowing and attempts to gain a sternal position. Kicking was evident but when attempts to become sternal ceased, the animals appeared to become deeply sedated and muscle relaxation was excellent. A few individuals walked several hundred meters and induction was characterized by a slowing of the gait, vocalization, stumbling and eventually sternal or lateral recumbency. Animals which were darted while excited, or those that stampeded immediately following dart impact, showed signs of induction characterized by aimless wandering, persistent trotting and stumbling. They usually required supplemental doses of carfentanil. Older bulls often seemed to resist the effects of the narcotic by struggling to remain standing, but all eventually became recumbent. For instance, after one bull was darted, he showed no signs of narcotization after 36 min. He was relocated in sternal recumbency at 63 min, but because

TABLE 2. Bison immobilization data on those animals requiring two or more doses of carfentanil to achieve complete sedation.

	n	Mean	Median	SE	Range
Carfentanil (μg/kg)	5	2.0[a]	2.2	0.2[d]	1.7–2.2
	5	1.0[b]	1.2	0.5[d]	0.4–1.6
	3	0.5[c]	0.4	0.2[d]	0.4–0.8
Induction time (min)	5	36.0	38.0	9.3	5.0–63.0
Arousal time after naloxone (min)	5	5.0	4.0	1.3	3.0–10.0
Total dose naloxone (mg)	5	210.0	200.0	23.1	175.0–300.0
Temperature (C)	5	39.7	39.7	0.4	38.8–40.8
Pulse (bpm)	4	82.0	93.0	14	40.0–100.0
Respiration (bpm)	5	30.0	36.0	3.8	18.0–36.0

[a] Initial dose of carfentanil and xylazine.
[b] Second dose of carfentanil.
[c] Third dose of carfentanil.
[d] Standard deviation.

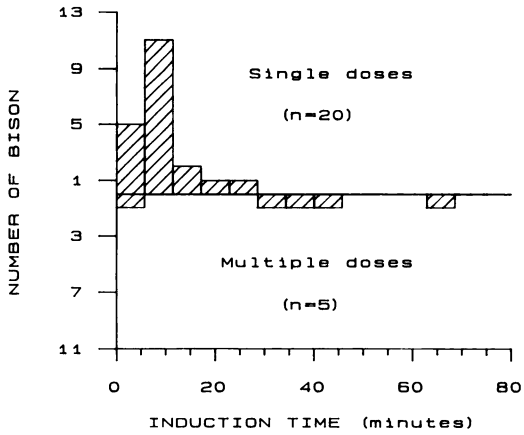

FIGURE 3. Comparison of induction times for two groups of North American bison. One group represents animals receiving single doses of carfentanil; the other, animals receiving two or more doses to achieve adequate sedation.

he was only partially sedated further doses of carfentanil were required. At 93 min he became laterally recumbent.

In most instances reversal of carfentanil with naloxone appeared effective. Only one individual showed signs of becoming "renarcotized," but this was difficult to assess in certain individuals since follow up in the wilderness area was difficult. Over 50% of the animals darted were relocated 24–48 hr after recovery and they appeared normal. Reversal of carfentanil with naloxone, i.m. and s.c., appeared to progress more smoothly and almost as rapidly compared to the combined routes i.v., i.m. and s.c. (total arousal time 8.8 ± 1.7 min versus 8.5 ± 1.4 min, respectively).

Multiple dosing with carfentanil had no significant effect on the total time to reversal. Alternatively, naloxone dosage significantly influenced the total time to reversal ($P < 0.05$); those receiving higher doses reversed more rapidly.

Three female bison (weight range 318–487 kg) were immobilized successfully with a mixture of carfentanil and xylazine, although multiple doses were required for one cow (Table 3). Female induction times were not significantly different from those of the 22 bull bison immobilized, but cows tended to react adversely to darting. This may be because cows occur in larger groups than males, and in such groups cows are often nervous and wary. Hence, due to social facilitation cows may be more likely to react adversely.

The single yearling male (weight 193 kg), initially darted with 150 mg xylazine, became recumbent after 2 min. He struggled when roped, and required an i.m. injection of carfentanil; 0.3 mg to achieve adequate sedation. Reversal of the xylazine with 50 mg yohimbine and carfentanil with 30 mg naloxone resulted in arousal in 1 min.

Physiological parameters were monitored in the 26 animals immobilized with carfentanil and xylazine. Carfentanil appeared to produce significant respiratory depression in a number of animals (low of 10, mean 24.0 ± 1.7 bpm). The pulse rate remained adequate (40–120 bpm) with the capillary refill time remaining less than 2 sec. Mean temperature, pulse and respi-

TABLE 3. Data on female bison immobilized with carfentanil and xylazine.

	n	Mean	Median	SE	Range
Carfentanil (μg/kg)	3	4.0	3.2	2.0[a]	2.5–6.0
Induction time (min)	3	23.0	28.0	7.6	8.0–33.0
Arousal time after naloxone (min)	3	7.0	5.0	2.1	4.0–11.0
Total dose naloxone (mg)	3	145.0	150.0	19.0	110.0–175.0
Temperature (C)	2	39.1	39.1	0.1	38.0–40.2
Pulse (bpm)	1	80.0	80.0	—	—
Respiration (bpm)	2	30.0	30.0	5.7	24.0–36.0

[a] Standard deviation.

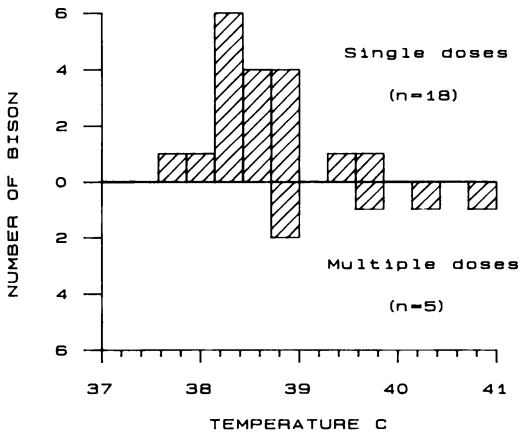

FIGURE 4. Comparison of body temperatures (C) of bison receiving single and multiple doses of carfentanil.

ration at induction were 38.8 ± 0.2 C, 76.0 ± 4.9 bpm, and 24.0 ± 1.6 bpm, respectively. Respiration following yohimbine reversal was 19 ± 1.41. Those bison which required multiple doses of carfentanil and xylazine had a mean temperature at induction of 39.6 ± 0.4 C which differed significantly from the 38.5 ± 0.2 C in animals receiving single doses ($P < 0.0002$) (Fig. 4). Pulse (81.5 ± 12.5 bpm) and respiration rates (30.0 ± 3.7 bpm) in the multiply-dosed animals did not differ significantly from animals receiving single doses. The temperature of a single male given xylazine was 40.5 C.

We observed two interesting behavioral aspects of bull bison induction and recovery. First, just prior to becoming recumbent, several animals (whether grazing, rubbing against trees or reacting aggressively towards us), resumed their previous behavior immediately after reversal of the narcotic. Second, following recovery a number of bulls interfered with our processing of other narcotized bulls by chasing us away. This behavior appeared to be more related to curiosity than to aggressiveness, but it was potentially dangerous.

Only one bull regurgitated significantly and this occurred during naloxone recovery; it did not result in any complications. Usually xylazine was reversed soon after recumbency with yohimbine. This was done to reduce the risk of regurgitation and bloat which can be a potential problem with xylazine sedation (Thurmon and Benson, 1986). We had difficulty in determining if this reversal was effective. There was no significant change in respiratory rates before and after yohimbine administration (24.0 ± 1.6 and 19.0 ± 1.4 bpm, respectively). This probably indicated a minimal effect of the sedative on the anesthesia. The dose of yohimbine selected was based on a recommended dose for domestic cattle (Kitzman et al., 1982).

The degree of analgesia with carfentanil appeared to be poor-to-moderate. Most bison reacted to ear tagging by raising or shaking their heads, initially resulting from our inability to place plastic ear tags through thick ear skin and cartilage.

DISCUSSION

Few reports of chemical immobilization of either captive or free-ranging bison are available (Haigh, 1976; Haugen et al., 1976; Boever, 1986). Undoubtedly, the paucity of information results from the existence of most populations living in artificial environments where bison movements are controlled by humans. Further, the large size of bison (up to 900 kg) and potential problems related to large ruminant anesthesia (Thurmon and Benson, 1986) may account for the few attempts to chemically restrain these large herbivores. Nevertheless, free-ranging bison have been immobilized using etorphine. Problems which have resulted include under-dosing of bulls, prolonged pursuit, and considerable animal-related stress. Haugen et al. (1976) successfully immobilized bulls using high doses of etorphine and 10-ml projectile syringes, although trotting and excitement prior to induction were noted. Additionally, many animals, despite sternal recumbency, were able to kick and remained alert. The three mortalities reported in this study (Haugen et al.) were perhaps related

to inadequate reversal. These authors considered etorphine to be a suitable drug for immobilizing bull bison, but it appeared that induction was not always uniform and the degree of sedation was inconsistent.

We found no reports of carfentanil and xylazine used to immobilize free-ranging North American bison although Haigh (1976) used fentanyl-based mixtures to immobilize a variety of ungulates, including two bison. Carfentanil is a piperidine derivative, with potent narcotic analgesic characteristics and a high safety margin. It is approximately 50 to 100% more potent than etorphine (De Vos, 1978; Parker and Haigh, 1982). The successful use of carfentanil on free-ranging wildlife was reported first by De Vos (1978) in South Africa. The drug was found to be safe and effective for a wide range of ungulates and pachyderms. More recently, carfentanil was used for immobilization of polar bears (*Ursus maritimus*) (Haigh et al., 1983), moose (*Alces alces*) (Haigh et al., 1982; Franzmann et al., 1984; Meuleman et al., 1984; Seal et al., 1985), elk (*Cervus elaphus*) (Meuleman et al., 1984; Stanely et al., 1984; Jessup et al., 1985), mule deer (*Odocoileus hemionus*) (Jessup et al., 1984), bighorn sheep (*Ovis canadensis*) and wild horses (*Equus caballus*) (Jessup et al., 1985), and a variety of zoo species (Stanely et al., 1984; Wiensner et al., 1984; Karesh et al., 1986).

Most bison live in reserves where restraint is possible without resorting to the use of narcotics. However, significant natural or re-established populations of bison still occur, and often it is not possible to capture entire or large segments of these populations in areas such as Yellowstone, Badlands, and Wood Buffalo National Parks. Therefore, information on restraint and capture techniques of these animals is needed. Particularly, this is important when data are necessary for conservation purposes. For example, at Wind Cave National Park there is an agreement between the State of South Dakota and the United States National Park Service, in which animals are to be tested regularly for disease, in particular brucellosis. In this herd, it is difficult to obtain blood from bulls, because they cannot be forced into corrals as easily as cows, as is also the problem at Badlands (Berger, unpubl. data). One of the ways proposed to collect blood from bulls was to kill them, but this plan no longer needs to be implemented since it is now feasible to immobilize bulls by using carfentanil. Further, our need for genetic sampling of live animals emphasizes the necessity of adopting successful restraint procedures.

We believe that the results of our study indicate several factors that should be considered when using carfentanil to immobilize bison. Firstly, adequate reversal can be achieved with approximately 100–150 mg naloxone/1 mg carfentanil. We believe that this is a minimum reversal dose. Secondly, "re-narcotization" or recycling appears to be a potential problem. Franzmann et al. (1984) found that when carfentanil was used to immobilize moose the animals recovered in an average time of 4.2 min using diprenorphine, but about 10% showed apparent recycling. Seal et al. (1985) used 50–80 mg naloxone with 4–8 mg diprenorphine, given by various combinations of injection routes, to reverse approximately 4 mg of carfentanil in moose. Animals lifted their heads in 3 to 4 min but they took from 25 to 150 min to reach a standing position. Jessup et al. (1985) reported the reversal time for carfentanil in bighorn sheep was 4.2 min, which was similar to that for naloxone and diprenorphine. Recycling was not reported. Recycling was noted as a problem after carfentanil use in bears (Haigh et al., 1983).

It appears that carfentanil has considerable potential as an immobilizing agent for North American bison. Induction appears to be uniform, with minimal excitement in a calm animal. The small drug volumes make darting easier and less traumatic. Table 4 gives recommended doses

TABLE 4. Dosage recommendations for carfentanil and xylazine in free-ranging North American bison.

Status	Carfentanil	Xylazine	Naloxone	Yohimbine
Calm bulls	1.5–1.8 mg/800–900 kg (1.8–1.9 μg/kg)	40–60 mg	100–150 mg/1 mg C	0.625 mg/1 mg X
Excited bulls	1.8–2.5 mg/800–900 kg (2.5–3.0 μg/kg)	50–70 mg	100–150 mg/1 mg C	0.625 mg/1 mg X
Females	1.5–1.8 mg/200–400 kg (4–7 μg/kg)	20–30 mg	100–150 mg/1 mg C	0.625 mg/1 mg X

for immobilizing free-ranging North American bison based on our experience. However, it must be noted that individual animals must be evaluated in terms of the degree of excitement, age and sex prior to determining a suitable dose for immobilization. Additional study is required to determine whether naloxone alone or various combinations of naloxone and diprenorphine are suitable agents for reversal of carfentanil in North American bison.

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